Spatially and temporally resolved measurement of water distribution in Nafion using NMR imaging

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Imaging water distribution through the profile of the electrolyte membrane represents a very efficient way of characterizing transport phenomena in fuel cells. Imaging techniques such as X-ray tomography or neutron scattering are capable of very high spatial and temporal resolutions but they suffer from their low accessibility. MRI is recognized as a powerful tool to image water with a fairly good spatial resolution but the spread of this technique across the fuel community has been hampered by its lack of sensitivity and its incompatibility with metallic materials. Nevertheless, MRI can be used in an efficient way to study transport in fuel cell components (membrane or membrane/electrode assembly (MEA)), provided that a specific hardware is developed.

In order to measure high resolution water profiles in Nafion we designed a NMR surface probe able to create a strong magnetic radiofrequency field close to the plane of the membrane (Figure 1). The use of a surface probe to characterize water distribution in Nafion was initially demonstrated by Zhang and coworkers [1]. Our probe is somewhat different and composed of a single-turn copper strip of 1.8 cm in diameter engraved on a PTFE substrate. The 2D geometry and the rigidity of the substrate facilitate the integration of the probe in a measurement cell. In the cell displayed on the figure the thin layer to be imaged (membrane / MEA) is sandwiched between two PMMA plates supplied with humid air at a controlled RH.

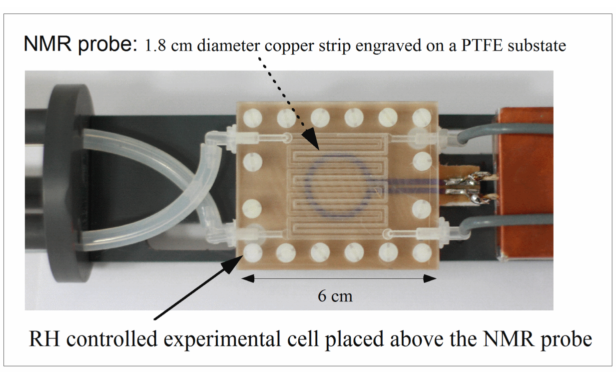

Figure1. NMR surface probe and experimental cell.

Using this new apparatus, together with an appropriate NMR sequence, we can measure the evolution of water profiles through a membrane with a spatial resolution better than 6 µm and a temporal resolution of less than 1 min per profile. These specifications are good enough to follow, for example, the drying of a membrane exposed to dry air on its both sides (Figure 2a) or its partial hydration when exposed to humid air on one side and dry air on the other (Figure 2b). The kinetics of water sorption or desorption can be obtained from these measurements by integrating the NMR signal along the profiles (Figure 2c).

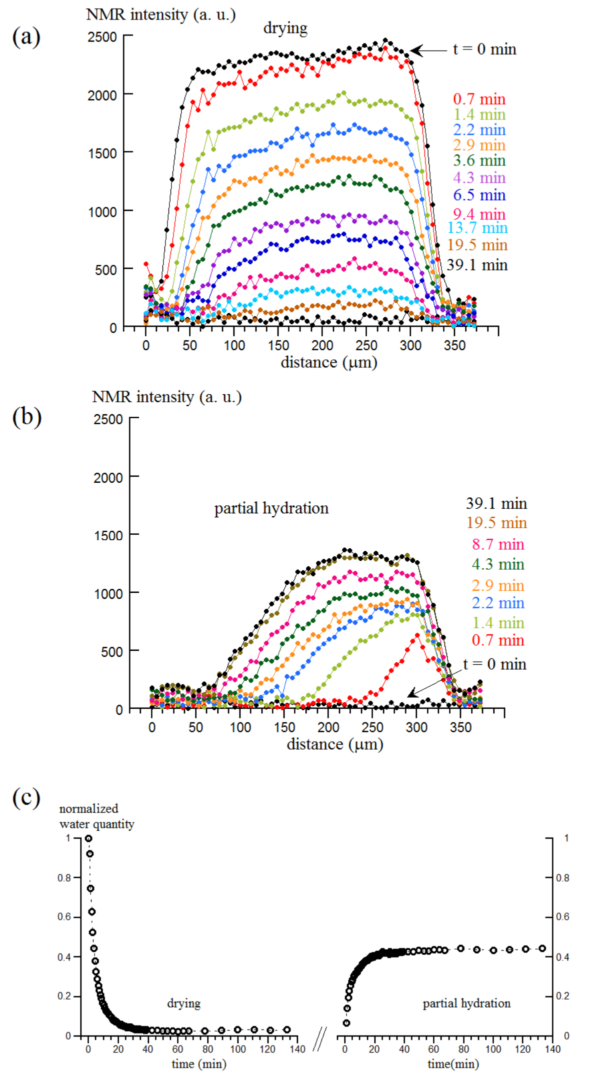

Figure2. Water profiles measured by MRI through a Nafion 1110 membrane during drying (a) and partial hydration (50% RH) from the right side (b). The spatial resolution is 5.9 µm/pixel and the temporal resolution 43 seconds/profile. Figure (c) presents the time variation of the total membrane water content.

Such time-resolved experiments can be performed in a range of experimental conditions (RH, flow rates…) to study water transport properties at steady or in transient states. Transport coefficients can be extracted from the shape and the time evolution of the water profiles, given that an appropriate transport model is used. In particular, this model must take into account the important swelling of the membrane during sorption and incorporate the water content dependence of water diffusion.

<u>References</u>:

[1] Z. Zhang, A.E. Marble, B. MacMillan, K. Promislow, J. Martin, H. Wang, and B.J. Balcom, *J. Magn. Reson.*, 194(2):245–253, 2008.